V. Claims

We claim:

1. A method for manufacturing a bearing unit component having a polycrystalline diamond compact with a non-planar bearing surface, the method comprising the steps of:
   (a) selecting a substrate material,
   (b) determining a substrate geometry,
   (c) determining substrate surface topography,
   (d) selecting diamond feedstock,
   (e) loading diamond feedstock,
   (f) reducing free volume in diamond feedstock by pressing,
   (g) preparing an assembly for sintering, and
   (h) sintering diamond feedstock and substrate into a polycrystalline diamond compact.
2. A method as recited in claim 1wherein said substrate material includes a metal or alloy that is selected from the group consisting of materials including titanium, aluminum, vanadium, molybdenum, hafnium, nitinol, cobalt, chrome, molybdenum, tungsten, cemented tungsten carbide, cemented chrome carbide, tantalum carbide, chrome carbide, fused silicon carbide, nickel, tantalum, and stainless steel.
3. A method as recited in claim 1 further comprising constructing a substrate with at least two substrate layers.

4. A method as recited in claim 3 further comprising placing a barrier layer on at least one of said substrate layers.

5. A method as recited in claim 4 wherein said barrier layer is an alpha coat.

6. A method as recited in claim 5 wherein said barrier layer is selected from the group consisting of niobium, tantalum, molybdenum and zirconium oxide coatings.

7. A method as recited in claim 1 wherein said step (a) includes selecting a plurality of substrate layers of different materials so that the combination of the properties of said substrate layers and said diamond, such as CTE and modulus, create balanced interface forces at locations where diamond and substrate interface.

8. A method as recited in claim 1 wherein diamond in said diamond feedstock has a coefficient of thermal expansion CTE_{Cd}, and wherein said substrate material has a coefficient of thermal expansion CTE_{sub}, and wherein CTE_{Cd} is not equal to CTE_{sub}.

9. A method as recited in claim 1 wherein said diamond in said diamond feedstock has a modulus M_{Cd}, and wherein said has a modulus M_{sub}, and wherein M_{Cd}, is not equal to M_{sub}.

10. A method as recited in claim 1 wherein said bearing unit includes a surface shell selected from the group of sintered diamond and sintered cubic boron nitride, a substrate shell and a substrate core.

11. A method as recited in claim 1wherein said substrate geometry includes a spherical substrate shell with a hole in it into which a substrate core may be placed, followed by a plug of substrate material to fill said hole.

12. A method as recited in claim 1wherein said substrate geometry includes two substrate hemispheres which when assembled form a receptacle into which a substrate core ball may be placed.

13. A method as recited in claim 1 wherein said polycrystalline diamond compact has a diamond table and a substrate, and wherein during said sintering sintering step said substrate experiences an expansion of at least one of its dimensions, and wherein at the conclusion of said sintering step said substrate contracts to create a residual stress field between said substrate and diamond table.

14. A method as recited in claim 11 wherein said substrate shell and said substrate core have CTE and modulus values that differ from each other.

15. A method as recited in claim 1wherein said substrate geometry is generally cylindrical with a concave hemispherical shape at one end.

16. A method as recited in claim 1 wherein said substrate geometry is generally spherical and has a curvature on one side of radius R1, and a curvature on another side of radius R2, where R2 is not equal to R2.

17. A method as recited in claim 1 wherein said substrate surface topography includes substrate surface topographical features.

18. A method as recited in claim 17 wherein said substrate surface topographical features are selected from the group consisting of protrusions and depressions.

19. A method as recited in claim 17 wherein said substrate surface topographical features will form a mechanical grip with a diamond table.

20. A method as recited in claim 1 wherein said diamond feedstock includes diamond of at least two different sizes.

21. A method as recited in claim 1 wherein said diamond feedstock is selected from single modal diamond feedstock and multi-modal diamond feedstock.

22. A method as recited in claim 1 wherein said diamond feedstock includes diamond particles in the size range of 0.5 to 80 microns.

23. A method as recited in claim 1 wherein said diamond feedstock includes a solvent-catalyst metal therein.

24. A method as recited in claim 1 wherein said diamond feedstock includes a solvent-catalyst metal therein, said solvent-catalyst metal includes an alloy that has a constituent selected from the group consisting of cobalt, chrome, molybdenum, tungsten, and nickel.

25. A method as recited in claim 23 wherein said diamond feedstock and said solvent-catalyst metal are present in a mass ratio of about 70:30.

26. A method as recited in claim 23 wherein said diamond feedstock and said solvent-catalyst metal are present in a mass ratio of about 85:15.

27. A method as recited in claim 23 wherein said diamond feedstock and said solvent-catalyst metal are present in a mass ratio of about 90:10.

28. A method as recited in claim 23 wherein said diamond feedstock and said solvent-catalyst metal are present in a mass ratio of about 97:3.

29. A method as recited in claim 23 wherein said solvent-catalyst metal is present in said diamond feedstock in an amount that is at least 1% by weight.

30. A method as recited in claim 23 wherein said solvent-catalyst metal is added to said diamond feedstock by a method selected from the group consisting of

attritor methods, power metal addition, vapor deposition and chemical reduction of metal into powder.

31. A method as recited in claim 1 wherein said diamond feedstock is dried and cleaned by firing in a furnace.

32. A method as recited in claim 31 wherein said furnace is selected from the group consisting of hydrogen furnaces, hydrogen plasma furnaces and vacuum furnaces.

33. A method as recited in claim 1 wherein said diamond feedstock includes a quantity of titanium carbonitride powder therein.

34. A method as recited in claim 1 wherein said diamond feedstock includes a binder material therein.

35. A method as recited in claim 1 wherein said loading of diamond feedstock includes spin spreading said diamond feedstock.

36. A method as recited in claim 1 wherein said loading of diamond feedstock includes pressing said diamond feedstock in a die.

37. A method as recited in claim 1 wherein said loading of diamond feedstock includes binding said diamond feedstock with a binder material.

38. A method as recited in claim 30 wherein diamond feedstock is bound by first preparing a binder solution, second mixing diamond feedstock with said binder solution, third drying said mixture of diamond and binder solution, and fourth shaping said bound diamond feedstock.

39. A method as recited in claim 31 further comprising the step of removing said binder from said shaped diamond feedstock.

40. A method as recited in claim 32 wherein said step of removing binder from shaped diamond feedstock includes pyrolizing said diamond feedstock and binder mixture.

41. A method as recited in claim 1 wherein said 36 further comprising the step of reduction of said binder in a furnace.

42. A method as recited in claim 37 further comprising the step of injection molding of said diamond feedstock into a desired shape.

43. A method as recited in claim 42 further comprising the step of reduction of said binder in a furnace.

44. A method as recited in claim 37 further comprising the step of solvent extraction of at least some of said binder.

45. A method as recited in claim 43 further comprising the step of reduction of said binder in a furnace.

46. A method as recited in claim 1 wherein said loading of diamond feedstock includes placing said diamond feedstock in a refractory metal can.

47. A method as recited in claim 1 wherein reduction of free volume in said diamond feedstock includes pressing said diamond feedstock.

48. A method as recited in claim 33 wherein reduction of free volume in said diamond feedstock includes pressing said diamond feedstock and binder.

49. A method as recited in claim 1 wherein reduction of free volume in said diamond feedstock includes causing said diamond feedstock to be packed to at least about 97% theoretical density.

50. A method as recited in claim 1 wherein said step of preparing an assembly for sintering includes preparing a heater assembly.

51. A method as recited in claim 50 wherein said heater assembly includes a material selected from the group consisting of graphite, amorphous carbon, pyrolitic carbon, refractory metals, and high electrical resistant metals.

52. A method as recited in claim 1 wherein said step of preparing as assembly for sintering includes preparing a pressure assembly.

53. A method as recited in claim 1 wherein said sintering step includes exposing said substrate and diamond feedstock to heat and pressure.

54. A method as recited in claim 53 wherein said sintering step includes exposing said substrate and diamond feedstock to about 40-68 Kbars of pressure.

55. A method as recited in claim 53 wherein said sintering step includes exposing said substrate and said diamond feedstock to heat of about 1200 to more than about 1500 degrees Celsius.

56. A method as recited in claim 53 wherein said sintering step includes exposing said substrate and said diamond feedstock to heat of about 1145 to more than about 1500 degrees Celsius

57. A method as recited in claim 53 wherein said diamond feedstock and said substrate are exposed to heat and pressure from less than about 1 minute to more than about 30 minutes.

58. A method as recited in claim 53 wherein said diamond feedstock and said substrate are exposed to heat and pressure for about 3-12 minutes.

59. A method as recited in claim 1 further comprising removing solvent-catalyst metal from diamond in said polycrystalline diamond compact.

60. A method as recited in claim 1 further comprising removing solvent-catalyst metal from diamond in said polycrystalline diamond compact by chemical leaching.

61. A method as recited in claim 60 further comprising replacing said solvent-catalyst metal in said diamond with another metal.

62. A method as recited in claim 1 further comprising finishing said polycrystalline diamond compact into a bearing unit component load bearing and articulation surface.

63. A method as recited in claim 62 wherein said finishing includes machining said polycrystalline diamond compact.

64. A method as recited in claim 63 wherein said machining includes electro discharge machining.

65. A method as recited in claim 62 wherein said finishing includes grinding diamond of said polycrystalline diamond compact.

66. A method as recited in claim 62 wherein said finishing includes polishing diamond of said polycrystalline diamond compact.

67. A method as recited in claim 62 wherein said finishing includes burnishing diamond of said polycrystalline diamond compact.

67. A method for manufacturing a polycrystalline diamond articulation surface for a bearing unit, the method comprising the steps of:

selecting an appropriate substrate material on which a table of polycrystalline diamond will be formed,

selecting an appropriate substrate geometry for forming a table of polycrystalline diamond thereon,

selecting a diamond feedstock,

assembling a said diamond feedstock and said substrate in a pressure transfer medium to form a pressure assembly in preparation for sintering, and

sintering said diamond feedstock and said substrate by subjecting said pressure assembly to heat and pressure in order cause formation of a polycrystalline diamond table on said substrate.

68. A method as recited in claim 67 further comprising roughing said polycrystalline diamond into a bearing unit articulation surface.

69. A method as recited in claim 67 further comprising finishing said polycrystalline diamond as a low friction bearing unit articulation surface.

70. A method as recited in claim 67 wherein said substrate geometry is selected from spherical concave and spherical convex.

71. A method as recited in claim 67 further comprising selecting substrate surface topographical features for providing an enhanced grip between said substrate and said polycrystalline diamond table.

72. A method as recited in claim 71wherein said substrate surface topographical features are selected from the group consisting of protrusions and depressions.

73. A method as recited in claim 71 further comprising permitting solvent-catalyst metal to sweep from said substrate into said diamond feedstock.

72. A method as recited in claim 71 further comprising using diamond feedstock that includes diamond particles of at least two different sizes.

73. A method as recited in claim 71 further comprising creating chemical bonds between said diamond feedstock and said diamond table.

74. A method as recited in claim 71 further comprising burnishing said polycrystalline diamond compact diamond surface.

75. A method as recited in claim 71 wherein said sintering is performed at between about 40 to 68 Kbars and at between about 1145 and 1500 degrees Celsius.

76. A method for manufacturing a component for use in a bearing unit comprising the steps of:

preparing a portion of substrate material,

forming a volume of diamond on said substrate material, and

polishing said diamond to a smooth, low-friction finish.

77. A method as recited in claim 76 wherein said step of forming a volume of diamond is selected from the group consisting of sintering, chemical vapor deposition and physical vapor deposition.

78. A method for manufacturing a bearing unit comprising the steps of:

preparing a portion of substrate material,

forming a volume of diamond on said substrate material,

polishing said diamond table to a smooth, low-friction finish,

forming a bearing unit member with an attachment portion suited for attachment to a human body,

attaching said substrate to said bearing unit member in a location where said volume of diamond will serve as at least one bearing surface for the bearing unit.

79. A method for manufacturing a component of a bearing unit, the method comprising the steps of:

selecting a hard bearing surface component,

selecting a substrate material,

determining a substrate geometry appropriate for the bearing unit component,

determining substrate surface topography,

selecting a feedstock,

loading the feedstock, and

applying heat and pressure to the feedstock.

80. A method as recited in claim 79 wherein said feedstock is selected from the group consisting of diamond, cubic boron nitride and wurzitic boron nitride.

81. A method as recited in claim 79 wherein said feedstock has a Knoop hardness of at least about 4000.

82. A method for manufacturing a bearing unit component having a polycrystalline diamond compact, the method comprising the steps of:

selecting a substrate material,

determining a substrate geometry,

determining substrate surface topography,

selecting diamond feedstock,

loading diamond feedstock into a can,

reducing fee volume in diamond feedstock,

sealing the can by use of electron beam welding,

placing the can into an assembly for sintering, and

sintering diamond feedstock and substrate into a polycrystalline diamond compact.

83. A method for manufacturing a bearing unit component having a polycrystalline diamond compact, the method comprising the steps of:

selecting a substrate material,

determining a substrate geometry,

selecting diamond feedstock,

adding metal to the diamond feedstock by chemical reduction,

loading diamond feedstock, and

sintering diamond feedstock and substrate into a polycrystalline diamond compact.

84. A method for manufacturing a polycrystalline diamond articulation surface for a bearing unit, the method comprising the steps of:

selecting an appropriate substrate material on which a table of polycrystalline diamond will be formed,

selecting an appropriate substrate geometry for forming a table of polycrystalline diamond thereon,

selecting a diamond feedstock,

selecting a mold material for use in sintering a polycrystalline diamond compact,

selecting a mold shape for use in sintering a polycrystalline diamond compact, assembling a said diamond feedstock, said substrate and said mold in a pressure transfer medium to form a pressure assembly in preparation for sintering, and

sintering said diamond feedstock and said substrate by subjecting said pressure assembly to heat and pressure in order cause formation of a polycrystalline diamond table on said substrate.

85. A method as recited in claim 84 further comprising a layer of material between said diamond feedstock and said mold.

86. A method as recited in claim 85 wherein said layer of intermediate material tends to prevent bonding of said diamond to said mold.

87. A method as recited in claim 84 wherein said mold material is a type which avoids bonding with said diamond.

88. A method as recited in claim 84 wherein said mold material tends to draw away from said diamond during the conclusion of sintering, so that said mold releases from said sintered polycrystalline diamond compact.

89. A method as recited in claim 88 wherein said mold contracts away from said polycrystalline diamond compact during the conclusion of sintering.

90. A method as recited in claim 88 wherein said mold expands away from said polycrystalline diamond compact during the conclusion of sintering.

91. A method as recited in 84 wherein said mold includes a solvent-catalyst metal that is utilized during said sintering.

92. A method as recited in claim 84 further comprising use of a separator ring in said pressure assembly.

93. A method as recited in claim 84 further comprising placing a layer of an intermediate material between said mold and said diamond feedstock, said intermediate material being one which tends to draw away from said polycrystalline diamond compact during the conclusion of sintering.

94. A method as recited in claim 84 wherein said intermediate layer is hexagonal boron nitride.

95. A method as recited in claim 84 further comprising removing solvent-catalyst metal from said diamond.

96. A method as recited in claim 95 wherein said step of removing solvent-catalyst metal includes chemical reduction.

97. A method for forming a bearing unit comprising:

selecting a diamond feedstock,

selecting a substrate,

assembling said feedstock adjacent said substrate in a pressure assembly,

sintering said feedstock and said substrate into a polycrystalline diamond compact.

98. A method for forming a bearing unit comprising:

selecting a diamond feedstock,

assembling said feedstock in a pressure assembly,

applying heat and pressure to said feedstock in said pressure assembly in order to sinter said feedstock into a continuous phase of polycrystalline diamond.

99. A method for forming a bearing unit comprising:

selecting a substrate metal,

selecting a substrate geometry,

building a layer of diamond on said substrate by a process selected from the group consisting of chemical vapor deposition and physical vapor deposition;

wherein said layer of diamond serves as an articulation surface for the bearing unit.

100. A method for manufacturing a non-planar component for a bearing comprising the steps of:

selecting a substrate material,

determining a substrate geometry,

determining substrate surface topography,

selecting diamond feedstock,

loading diamond feedstock,

preparing a pressure assembly for sintering, and

sintering diamond feedstock and substrate into a polycrystalline diamond compact,

placing said sintered polycrystalline diamond compact on a centerless grinding machine having a grinding wheel and a regulating wheel,

allowing said grinding wheel to turn against said sintered polycrystalline diamond compact in order to remove material therefrom, and

allowing said regulating wheel to turn against said sintered polycrystalline diamond compact in order to keep said polycrystalline diamond compact in contact with said grinding wheel.

101. A method as recited in claim 100 wherein said grinding wheel rotates faster than said regulating wheel.

102. A method as recited in claim 100 wherein said sintered polycrystalline diamond compact turns on said centerless grinding machine at a rate of from about 2000 to 3000 linear feet per minute.

103. A method for forming a non-planar component for use in a bearing comprising the steps of:

forming a volume of non-planar diamond for use as a bearing surface,

placing said non-planar diamond on a centerless grinding machine having a grinding wheel and a regulating wheel,

allowing said grinding wheel to turn against said non-planar diamond in order to remove material therefrom, and

allowing said regulating wheel to turn against said non-planar diamond in order to keep said non-planar diamond in contact with said grinding wheel.

104. A method for manufacturing a bearing unit component having a polycrystalline diamond compact, the method comprising the steps of:

selecting a substrate material that has material properties different than the material properties of diamond,

determining a substrate geometry,

determining substrate surface topography,

selecting diamond feedstock,

loading diamond feedstock into a can,

reducing fee volume in diamond feedstock,

placing the can into an assembly for sintering, and

sintering diamond feedstock and substrate into a polycrystalline diamond compact, causing said substrate material to expand,

terminating said sintering step so that said substrate material contracts to a dimension 0.01% to 1.0% smaller than its dimension prior to sintering in order to create residual stresses in said compact, said residual stresses being less than that which would exceed the tensile strength of any of the substrate, the diamond and the diamond to substrate interface.